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EDITORIAL NOTE

Plant invasions: theoretical and practical challenges

David M. Richardson · Curtis C. Daehler · Michelle R. Leishman · Aníbal Pauchard · Petr Pyšek

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Introduction

The conference series on "*Ecology and Management of Alien Plant Invasions*" (*EMAPI*) has become the premier international forum for scientific research in the field of plant invasions. The *EMAPI* story began in April 1992 with the 1st International Workshop on the Ecology and Management of Invasive Riparian and Aquatic Plants at Loughborough University in the United Kingdom (de Waal et al. 1994). *EMAPI 2* was held in the Czech Republic in 1993 (Pyšek et al. 1995). Since then *EMAPI* conferences have been held every 2–3 years, in Arizona (Brock et al. 1997), Germany (Starfinger et al. 1998), Italy (Brundu et al. 2001), the United Kingdom (Child et al. 2003), Florida, USA, Poland (Tokarska-Guzik et al. 2008a), and Australia (see Tokarska-Guzik et al. 2008b for a brief summary of the *EMAPI* history).

EMAPI has been influential in shaping the research agenda for the study of plant invasions worldwide. Most conferences yielded an edited book (see above) and over the years the *EMAPI* book series has become a source of valuable data and case studies on invasive species from many regions of the world (Richardson 2002). Probably more important though have been the collaborations that have been forged through the personal contacts made at *EMAPI* gatherings. The meetings were initially focussed in Europe and, to a lesser extent, North America. As the quality of presentations and the range of topics increased over the years, *EMAPI* became an indicator of progress in invasion research in Europe. *EMAPI 7* was important in that it was held jointly with the Weed Science Society of America, thus forging new ties between plant invasion ecology and weed science and attracting many participants from North America (Richardson et al. 2004). *EMAPI* is now truly global in its reach: *EMAPI 9* was held in Australia and *EMAPI 10* in South Africa.

D. M. Richardson (✉)
Centre for Invasion Biology, Department of Botany and Zoology, Stellenbosch University, Matieland 7602, South Africa
e-mail: rich@sun.ac.za

C. C. Daehler
Department of Botany, University of Hawaii, 3190 Maile Way, Honolulu, HI 96822, USA

M. R. Leishman
Department of Biological Sciences, Macquarie University, Sydney, NSW 2109, Australia

A. Pauchard
Laboratorio de Invasiones Biológicas, Facultad de Ciencias Forestales, Universidad de Concepción and Institute of Ecology and Biodiversity, Concepción, Chile

P. Pyšek
Institute of Botany, Academy of Sciences of the Czech Republic, 252 43 Průhonice, Czech Republic

P. Pyšek
Department of Ecology, Faculty of Science, Charles University, Viničná 7, 128 01 Prague 2, Czech Republic

The scope of *EMAPI* has grown tremendously, in line with the increasing complexity of issues associated with plant invasions worldwide. Those wanting to stay informed of developments regarding plant invasions now need to be informed not only about the ecology and biogeography of invasive species, but also about communication, education and social marketing, global change biology, mapping and modelling methods, molecular biology, policy studies, restoration ecology and risk analysis, to name but a few fields (Richardson and Pyšek 2008; Pyšek and Richardson 2010). The diversity of issues facing those interested in plant invasions was clearly evident in the programme for *EMAPI 10*, hosted by the Centre for Invasion Biology in Stellenbosch, South Africa in August 2009 (Alexander and Pauchard 2009). The meeting, attended by about 230 delegates from all corners of the world, comprised 31 sessions covering a spectrum of topics, ranging from the ecological and evolutionary mechanisms driving invasions, modelling and prediction of invasion patterns and dynamics, designing and implementing effective management strategies, to various issues relating to education and raising awareness of invasions.

Plant invasions: theoretical and practical challenges—selected papers from *EMAPI 10*

This special feature of *Biological Invasions* presents a sample of 15 papers from *EMAPI 10*. The featured papers give a flavour of the diversity of issues that were deliberated at the conference and provide a reasonable cross section of the current research interest in plant invasion ecology (Richardson 2011). This editorial places these contributions in context.

Six broad themes can be recognized among the 15 papers in this special feature:

- "big-picture" analyses to derive new insights on invasion dynamics for large regions and biomes;
- detailed studies on major invasive species, drawing on insights from conspecific and congeneric invasions in other regions;
- genetic studies to elucidate invasion processes and inform management strategies;
- assessment of the relative role of climate matching in shaping invasion patterns through the analysis of patterns of distribution of invasive species along elevational gradients;
- assessing potential changes in invasion dynamics and impacts under climate change;
- new approaches for integrating advances in the understanding of invasion ecology to improve management.

The availability of detailed lists and maps of invasive species in many parts of the world is paving the way for informative analyses of invasion patterns and processes to shed new light on the determinants of invasion success. Three such studies are included in this special feature. Foxcroft et al. (2010) assembled a database of key invasive species in savanna ecosystems around the world to explore why this biome, especially in Africa, has fewer widespread invasive species than other major biomes. Their results point to the pivotal roles of introduction pressure, the evolutionary history of the receiving environment, historical and biogeographical issues relating to regions of origin of introduced species, and adaptation to fire in explaining key differences in invasion patterns in savannas on different continents. Milton and Dean (2010) examine the current extent and impacts of invasive alien plants in arid ecosystems, with a focus on southern Africa examples. They identify key and unique drivers of invasibility in these systems which define crucial constraints and provide opportunities for management interventions. In another study, Trueman et al. (2010) used a detailed inventory of the invasive flora of the Galapagos Islands to determine the relative roles of residence time and human-mediated propagule pressure in shaping the observed patterns. These three papers point to the huge potential for gaining crucial information through macroecological studies. There is much scope for similar studies for many other regions. Such studies are crucial for generating hypotheses and research questions to guide experimental research (Richardson and Pyšek 2006).

A useful approach for framing the study of invasive plant taxa at a given site is to assess their performance (or that of their close relatives) elsewhere in the world to identify key determinants of invasiveness and invasibility. Among plant genera with invasive taxa in many parts of the world, and for which this comparative approach has proved particularly useful, pines (genus *Pinus*) have emerged as a superb model system (Richardson 2006; Simberloff et al. 2010). Langdon et al. (2010) present a detailed

assessment of the invasion history of *Pinus contorta* in Chilean Patagonia. They show that, at the early stage of invasion of this species in this region, invasion patterns are largely explained by proximity to seed sources. However, based on experience with this species as an invader elsewhere, they predict massive landscape-scale invasions in areas with particular climatic and vegetation features.

Molecular ecology is revolutionizing insights on introduction and invasion histories. Two studies in this special feature reveal the opportunities afforded by this field of study in plant invasion ecology. Fennel et al. (2010) examined genetic variation in invasive populations of *Gunnera tinctoria* from many parts of the world at three spatial scales (inter-regional; within-region; and high-resolution local scale). Their results show, among other things, that gene flow is an important determinant of successful invasions, balancing out the potentially fitness-reducing effects of genetic bottlenecking by sustaining the level of diversity needed to maintain high population fitness. Insights from genetic studies have important applications in guiding management strategies. Many plant species with commercial importance in horticulture are serious invaders, but molecular studies are sometimes essential for correctly identifying difficult taxa or determining genetic origins and relatedness of horticultural breeds and invading populations. Le Roux et al. (2010) studied the molecular systematics and ecology of *Anigozanthus* species (kangaroo paws). Several species of this Australian genus are widely used as ornamental plants in South Africa, where self-sown populations have been recorded. The study sought to identify the invasive taxa, to determine genome compatibility and assess the likelihood of hybridisation between traded taxa. The identity of two invasive species was confirmed, and sound evidence was provided to support the restriction of the use of all *Anigozanthus* taxa since many have relatively compatible genomes and may produce fertile hybrids which could well be invasive.

Climate is a crucial element determining the fate of introduced plants. There are many opportunities for improving our understanding of the role of climatic factors in shaping invasions by merging observations from natural experiments with results from manipulative experiments. Three papers in this issue present innovative analyses of the performance of invasive species along elevational gradients. Haider et al. (2010) recorded the presence of alien annual plant species along an elevational gradient in the Canary Islands. They found that alien species richness is a function of complex interactions between altitude, which affects climate, and habitat context (natural or anthropogenic). Because both climate and habitat changes are expected in the future, the findings of Haider et al. (2010) require us to expect dynamism in alien species distributions. Interestingly, introductions from the Mediterranean were not differentially distributed from other temperate introductions. Jacobs et al. (2010), in contrast, found partitioning of species across elevation gradients in Hawaii based on bioclimatic origins (tropical versus temperate). Yet, temperate species introduced to the tropics may exhibit novel growth and life history patterns. Ansari and Daehler (2010) studied the performance of a temperate biennial invader from Eurasia, *Verbascum thapsus,* along an elevational gradient in Hawaii and found increasing life spans (>3 years) at high elevations, contradicting patterns in temperate regions where high-elevation plants have shorter life spans. All of these studies emphasize the importance of climate in understanding invasive species patterns and behaviour.

As climate change affects invasive plants, it will also change interactions between native and invasive species. Gallagher et al. (2010) used species distribution models for five exotic vines in eastern Australia to assess how projected future changes in the distribution of climatically suitable habitat may overlap with remnants of an endangered ecological community in the region. This type of approach will be increasingly important for the development of mitigation strategies for exotic plant species in future climates.

Five papers in the special feature address issues relating to the management of plant invasions. Esler et al. (2010) address the gap between *knowing* and *doing* in the literature on invasion ecology. They conclude that the knowledge base in this field is dominated by research oriented towards the generation of knowledge, while research aimed at applying or implementing such knowledge is poorly represented, and that which exists is not at the (local) scale appropriate for management. Another paper provides one potential means of narrowing the "knowing-doing" gap in the field of biological invasions. Shaw et al. (2010) describe the outcome of facilitated dialogue between scientists and managers of biological invasions at two international conferences (including *EMAPI 10*).

Risk assessment is increasing in importance as a central tenet of the management of biological invasions worldwide. The Australian weed risk assessment system is used in many countries for pre-border screening (Gordon et al. 2010). Mc Clay et al. (2010) evaluate the usefulness of this system for the prediction of plant invasiveness in Canada. For post-border management, increasing emphasis is being placed on the use of decision-support tools to assist in assigning priority to various potential interventions. Krug et al. (2010) apply a spatio-temporally explicit simulation model to explore the efficiency of different strategies for clearing of invasive alien plants under different budget scenarios. Biological control is a pivotal part of integrated management programmes in many parts of the world. De Lange and van Wilgen (2010) undertake an economic assessment of the contribution of biological control to the management of invasive alien plants and to the protection of ecosystem services in South Africa. Their results provide important evidence to support ongoing investment in this form of control.

Conclusions

Studies on vascular plants dominate the literature in invasion ecology (Pyšek et al. 2008) and the number of dimensions and aspects under investigation is growing very rapidly (Richardson 2011). Sessions at *EMAPI 10* covered a bewildering diversity of geographical areas, research questions and taxa. The focus of presentations ranged from theoretical considerations of invasion dynamics to practical considerations of the best ways to control particular species. *EMAPI* conferences provide an excellent common meeting ground for people with an interest in plant invasions from many perspectives. The good mix of researchers and practitioners/managers at *EMAPI* meetings shows that some progress is being made towards forming a transdisciplinary bridge between disciplines that do not usually interact, although much more work is needed in this direction (Shaw et al. 2010). *EMAPI* provides good opportunities for media and education at the national level for the host nation, and hopefully an impetus for invasion biology to be included in national research and management priorities.

Successive *EMAPI* meetings give snapshots of the changing dimensions of plant invasion ecology. We suggest that *EMAPI 10* highlighted, in particular: (1) the importance of new techniques being applied to old questions in invasion ecology, e.g., the use of molecular techniques for understanding invasion histories, species distribution modelling to predict distribution and the impact of invasive plants under climate change; (2) the increasing appreciation of the role of genetics; and (3) the value of large-scale macroecological studies made possible by increasing data availability, as opposed to a series of case-studies on individual species.

EMAPI 11 will be held in Hungary in August 2011. Details are available from Zoltán Botta-Dukát (e-mail: bdz@botanika.hu), or at http://www.emapi2011.org.

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